

AMENDMENTS TO THE SPECIFICATION

Please replace paragraph [0023] with the following amended paragraph:

[0023] With continued reference to Figure 2, the electron beam subsystem 27 is comprised of an electron beam gun 11; an electron beam control element (~~not shown~~) 28 which is one means for controlling and managing the electron beam emitted from the electron beam gun 11 and wherein the electron beam control element is electronically connected to the electron beam gun 11 and a computer system 22, which is a component of an instrumentation subsystem (~~not completely shown~~) 29; at least one focusing coil (not shown); at least one deflection coil (not shown); an electron beam power supply 15 electrically connected to a power distribution subsystem 17, the electron beam gun 11, the electron beam control element, the at least one focusing coil, and the at least one deflection coil; or any combination. Further, the focusing and deflection coils may be integrated into the electronic beam gun 11. In an embodiment, the electron beam subsystem further comprises an auxiliary vacuum pump (~~not shown~~) 40, a service panel (~~not shown~~) 41, outputs and inputs (not shown), a user interface screen (~~not shown~~) 42, or any combination. In an embodiment, the electron beam gun 11 generates a focusable electron beam with a low accelerating voltage (below about 15 kV) and with a maximum beam power in the range of from about 3 to about 5 kW and operates using about 110 V input power. However, any commercially available power source, wherein the current global voltage range is from about 100V to about 240V, can be used. This embodiment provides sufficient power density for the electron beam freeform fabrication process and still meets safety considerations for radiation shielding. However, optional maximum beam power ranges (up to about 10 kW) as well as optional accelerating voltages (from

about 15 kV to about 60 kV) may be used. In an embodiment, the electron beam gun is compact in size and operates using the vacuum from the process environment, thereby eliminating the requirement for auxiliary vacuum pumping of the electron beam gun. However, in one embodiment, the electron beam gun further comprises an auxiliary vacuum pump (~~not shown~~) 40. The electron beam subsystem is designed for an electrically conductive path to ground the system. Furthermore, in an embodiment, the electron beam subsystem further comprises an enhanced capability by adding the ability to move the electron beam gun using translation in X, Y, Z, tilt in the X-Z or Y-Z planes, or rotation (not shown). This option allows greater flexibility, better efficiency of space utilization within the sealed container 10, and greater complexity of parts that can be built. This ability to move the electron beam gun will require an electron beam positioning subsystem 43 comprised of at least one electron beam gun motor (not shown), at least one electron beam gun position sensor (not shown), and a programmable motor control element (not shown) attached to the electron beam gun to affect the mobility of the electron beam gun. In one embodiment, the programmable motor control element is integrated with the electron beam control element. In another embodiment, the programmable motor control element is independent to the electron beam control element.

Please replace paragraph [0025] with the following amended paragraph:

[0025] An electron beam deposition process in a vacuum is preferred to prevent attenuation of the electron beam and ionization of gases in the process environment. Working in a vacuum also provides a clean atmosphere to prevent contamination of the metal during

the deposition process. In another embodiment, the electron beam deposition process is not performed in a vacuum and thus, no vacuum subsystem is included in the solid freeform fabrication apparatus. With continued reference to Figures 1, 2, and 3, in an embodiment, the preferred vacuum level is about 10^{-4} torr to about 10^{-6} torr for proper operation of the electron beam gun 11. In an embodiment, the vacuum subsystem 38 is comprised of at least one pump (for example, at least one scroll pump 19, at least one turbomolecular pump 18, at least one ion pump 20, or any combination) wherein the at least one pump is interconnected to the sealed container 10 and to each other by at least one duct 25 and at least one valve 21. Further, in an embodiment, at least one vacuum subsystem sensor (not shown) is installed at predetermined locations in regards to the pumps, ducts, valves, or any combination. In still a further embodiment, at least one filter is installed at predetermined locations in regards to the pumps, ducts, valves, or any combination. In an embodiment, the at least one pump and at least one valve are electronically connected to a vacuum subsystem control element (~~not shown~~) 53 that records and processes sensor data as well as controls the at least one pump and valve. In an embodiment, the vacuum subsystem control element is comprised of at least one vacuum subsystem sensor (not shown) electronically connected to the instrumentation subsystem (discussed later) and electrically connected to the power distribution subsystem. In another embodiment, the vacuum subsystem control element (~~not shown~~) 53 further comprises a microprocessor (not shown) electronically connected to the at least one sensor and to the instrumentation subsystem as well as electrically connected to the power distribution subsystem. In an embodiment, the vacuum subsystem control element (~~not shown~~) 53 further comprises a circuit board (not shown) and firmware (not shown),

wherein both elements are electronically connected to the at least one sensor and to the instrumentation subsystem as well as electrically connected to the power distribution subsystem. In an embodiment, at least one scroll pump 19 achieves a rough vacuum, and serves as a backing pump for at least one turbomolecular pump 18. In a second embodiment, at least one low vacuum pump is used to achieve a rough vacuum. In a third embodiment, at least one roughing pump is used to achieve a rough vacuum. In one embodiment, at about 1 torr, the at least one turbomolecular pump 18 switches on to evacuate quickly down to about 10^{-6} torr. In a second embodiment, at about 1 torr, at least one high vacuum pump is used to evacuate quickly down to about 10^{-6} torr. In a third embodiment, at about 1 torr, at least one cryopump is used to evacuate quickly down to about 10^{-6} torr. In a fourth embodiment, at about 1 torr, at least one diffusion pump is used to evacuate quickly down to about 10^{-6} torr. In one embodiment, once the sealed container 10 reaches about 10^{-6} torr, the at least one valve 21 to the at least one turbomolecular pump 18 closes and the at least one turbomolecular pump 18 shuts off to protect the high speed rotating vanes from damage that may occur due to sudden loading or changes in various forces on the at least one turbomolecular pump 18. The at least one ion pump 20 is activated to maintain high vacuum and to remove any outgassing or metal vapor resulting from the fabrication process. In a second embodiment, there is no ion pump and the at least one turbomolecular pump 18 remains on after evacuation to about 10^{-6} torr. In an embodiment, the at least one turbomolecular pump is equipped with contactless electromagnetic bearings with its own feedback control to help protect from damaging the at least one turbomolecular pump due to changes in forces or irregular loading conditions. In an embodiment, a further precautionary measure includes

mounting all pumps with shock suppression (not shown) to protect all pumps from damage due to irregular loading conditions.

Please replace paragraph [0029] with the following amended paragraph:

[0029] In an embodiment, a positioning subsystem moves the substrate 32 while allowing the electron beam to remain stationary. With continued reference to Figures 1, 2, and 3, in an embodiment, the multi-axes positioning subsystem 12 is comprised of a movable platform 14, a positioning subsystem control element ~~(not shown)~~ 44, at least one positioning subsystem sensor (for example, rate and location sensors) (not shown), at least one positioning subsystem motor 45, means for providing electrical continuity (for example, a grounding element) (not shown), means for providing thermal and electrical isolation (for example, insulators) (not shown), means for providing protective shielding (not shown), and means for clamping a base plate in place (not shown). The multi-axes positioning subsystem 12 is powered by and electrically connected to the power distribution subsystem 17. As illustrated in Figure 2, in one embodiment, the positioning subsystem has four axes: X, Y, and Z linear axes, plus a-axis rotation in the X-Y plane. The four-axes positioning subsystem 16, which is a specific embodiment of a multi-axes positioning subsystem, allows sufficient flexibility for more detailed process development and the ability to produce complex parts. In a second embodiment, a five-axes positioning subsystem (not shown) that includes a tilt capability, which tilts the platform in either the X-Z or Y-Z plane is used. In one embodiment, the positioning subsystem control element ~~(not shown)~~ 44 is comprised of at least one positioning subsystem sensor (not shown) electronically connected to the instrumentation subsystem.

The positioning subsystem control element is electrically connected to the power distribution subsystem 17. In another embodiment, the positioning subsystem control element is further comprised of a microprocessor (not shown). In still another embodiment, the positioning subsystem control element is further comprised of a circuit board and firmware (not shown). The electron beam freeform fabrication process typically orients the electron beam vector normal to the surface on which the deposit is being built. This tilt capability enables positioning of the substrate 32 at different angles from 0° (platform normal is parallel to the electron beam vector) to 90° (platform normal is perpendicular to the electron beam vector) to allow enhanced flexibility and capability to build complex geometries and overhangs.

Please replace paragraph [0033] with the following amended paragraph:

[0033] In an embodiment, the deposition subsystem is a wire feed subsystem 13 ~~that consists comprised~~ of at least one wire feed motor (providing tension on the wire and pulling or pushing the wire through the feeding mechanism) ~~(not shown)~~ 48, a feeding mechanism ~~(not shown)~~ 49, a straightening mechanism (not shown), a nozzle 33, an external wire feed controller ~~(not shown)~~ 51, wire feed subsystem sensors (for measuring wire feed rate) (not shown), means for mounting a spool of wire (not shown), ~~and~~ the wire spool containing a wire feed supply ~~(not shown)~~ 46, and a wire feed housing 47 contained within the sealed container 10 and capable of accommodating the wire feed supply. In one embodiment, the nozzle may incorporate at least two orthogonal positioners for directing the wire precisely into the molten pool. The at least one wire feed motor and wire spool are contained within the sealed container 10 to eliminate damaging the wire

feedstock feeding through the sealed container wall. The wire feed subsystem 13 is compact in size to locate it close to the process zone. In an embodiment, the feedstock supply is metal wire. Powdered metal feedstock requires gravity or flowing gas to direct the powder into the molten pool. For operating in a vacuum at microgravity, neither of these powder delivery methods will work. In addition, containment and handling of powdered metal poses significant safety issues in a microgravity environment. However, for terrestrial applications, the deposition subsystem may be a powder delivery subsystem. The use of wire feedstock eliminates the need for flowing gas and provides about 100% feedstock usage efficiency, resulting in the minimum mass and virtually no waste products. The wire feed subsystem 13 is capable of feeding very small diameter wires at both high and low speeds, enabling a range of deposition rates and fine detail to be achieved within this electron beam freeform fabrication system. In an embodiment, a plurality of wires may be fed from the wire feed subsystem. The wire feed subsystem 13 is vacuum compatible for location within the vacuum system close to the process zone. One-pound wire spools are preferred, but other spool sizes may also be used.